

## First Environmental Data from the Engineering Test Stand (ETS)

**Environment Mission:** To understand and mitigate contamination (particulate, chemical) issues associated with EUV lithography.

**Acknowledgements:**

Mike Malinowski, Philip Grunow, Chip Steinhaus, Miles Clift, Daniel Dedrick, Dan Rader, Samuel Graham, Mike Tootle, Alvin Leung, Steve Haney

--Sandia National Laboratories

Environmental Efforts Support by International Sematech (Carmelo Romeo)

## EUV Engineering Test Stand (ETS)

**Main chamber:** (Projection optics, wafer stage, reticle stage, metrology trays, isolation system)

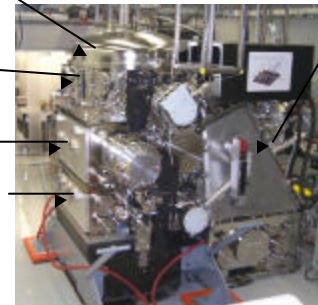
Reticle Zone

Optics Zone

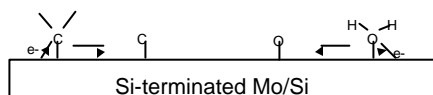
Wafer Zone

**Illuminator**

(LPP source, condenser optics, pupil optics)



## O, C Contamination Mitigation Efforts



Gas Blend: Balance C-deposition, oxidation with a blend of hydrocarbon (HC) gas, water vapor.

*Initial Goal: Prevent optics oxidation*

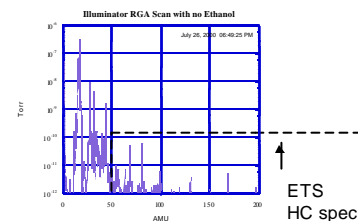
Use ethanol ( $\text{CH}_3\text{CH}_2\text{OH}$ ), EtOH for hydrocarbon gas to prevent optic oxidation.

## Carbon Contamination Mitigation

### Three-fold Approach:

1. Minimize sources of hydrocarbon gases in ETS construction:
  - Screen materials and components for low HC outgassing (>250 items tested to date).
2. Inhibit the growth of carbon deposits with Gas Blend approach:
  - Exploring the use of  $\text{O}_2$  to mitigate, clean carbon contamination.  
*(see Mike Malinowski's talk this session) , International Sematech*
3. Develop effective in-situ methods of optic cleaning:
  - exploring the use of RF oxygen discharge .  
*(see Samuel Graham's talk this session), International Sematech*

## Negligible Non-EUV Contamination in Illuminator



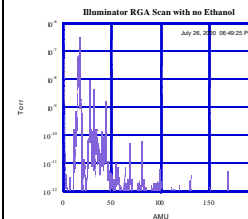
Data Acquired for Non-line-of-site Witness Plates:

<u>Witness Exposure</u>	<u>At.% C (<math>\pm 2</math>)</u>	
Pre-exposure Control	18	
1 month	18	Note: ~ 40 atomic % = ~ 3 Å of graphitic C.
3 months	21	
10 months	10	

\ Negligible non-EUV contamination of Illuminator optics despite repeated vents, installations, pumpdowns.

## First Exposure Tests of Illuminator Environment

Previous experiments show electron beams can be used to simulate EUV exposure, acquire rapid learning.



### Electron Beam Test

2kV electrons, 1.5  $\mu\text{A}/\text{mm}^2$ , 6 hours

(in Illuminator environment)

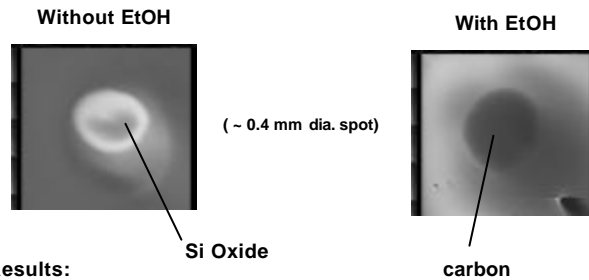
(~ 3X C3 flux)

Mo/Si optic

### Issues:

- Is the Illuminator environment oxidizing or carbonizing?
- What is the optics contamination rate of the Illuminator environment?
- How well are contamination mitigation strategies working?

## SEM Pictures of Electron Test Spots



### Results:

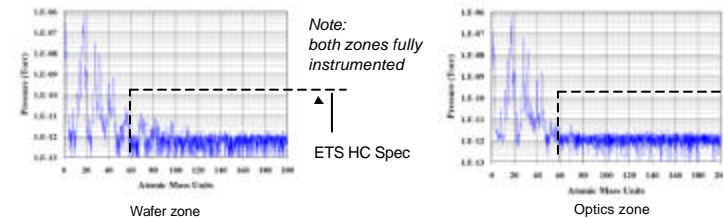
Illuminator Environment: *Oxidative ( $H_2O$ /EUV oxidation)*

Illuminator Environment + EtOH: *No oxidation, carbon deposition*

Initial estimate of ETS C3 carbon deposition rate at full power  
(with no C mitigation attempted):  $\sim 0.25 \text{ \AA/hr}$

*Mitigation will be possible, see Mike Malinowski's talk this session*

## Excellent Control of High Mass Hydrocarbons Achieved in Main Chamber



### High Mass Hydrocarbon Control due to:

- Outgas test program (>250 items tested)
- Vacuum compatible design
- Careful cleaning of parts, pre-baking of cables and sub-assemblies
- Clean assembly procedures
- EtOH will probably be needed in Main Chamber to prevent  $H_2O$ /EUV optics oxidation

## **Summary**

1. Environmental issues are understood.
2. Mitigation approaches have been validated.
3. ETS optics contamination is manageable.